Food Supply Chain Consequences of New Responses to Livestock Epidemics

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23-26, 2006

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This article studies supply chain consequences from applying the new—more socially acceptable—strategy of emergency vaccination instead of the large-scale killing of healthy animals for controlling livestock epidemics. We consider an outbreak of foot and mouth disease in a densely populated livestock area of the Netherlands. From an epidemiological perspective, simulation results show that emergency vaccination significantly reduces the size of an epidemic, both in terms of the length of an outbreak and in the number of animals killed. However, in a worst-case situation, not destroying the vaccinated animals after the end of the epidemic leads to additional consequential losses for food supply chains involved of about Euro 200 million. A business case illustrates that the exact size of these losses depends on specific supply volumes and marketing strategies. Calculations provide a basis for addressing cost sharing issues and loss reducing opportunities of new responses to livestock epidemics.

Key words: livestock epidemics, financial impact, consumer acceptance.

For a bit more than a decade livestock epidemics, such as foot and mouth disease, have been controlled through stamping-out, including the (large-scale) killing of healthy animals. The societal impact of these policies became evident in the Netherlands during the 1997/98-outbreak of classical swine fever and, even stronger, during the 2001 and 2003 epidemics of foot and mouth disease and avian influenza respectively. Public debates induced responsible authorities to declare that with future epidemics animal lives

will be saved as much as possible. Stamping-out will still be applied for infected and contact herds, but wide-spread pre-emptive culling will not be enforced anymore. Instead, emergency vaccination will be used to prevent the spread of a disease. Vaccines are available for foot and mouth disease (FMD) and classical swine fever (CSF), not for Avian Influenza (AI).

Although emergency vaccination has already been possible for many years, expected economic consequences, for instance from export restrictions, generally restrict its practical usefulness. The only recent example of emergency vaccination can be found in the 2001-FMD epidemic in the Netherlands. However, all vaccinated animals were destroyed afterwards, again for economic reasons. The current intention to apply vaccination *without* culling the vaccinated animals does not imply that "the economics" are solved but does show the increased importance of public pressure against killing healthy animals.

Previous work on the economics of livestock epidemics does either not include the "emergency vaccination without destroying the vaccinated animals" option (Berentsen, Dijkhuizen, and Oskam 1992; Meuwissen et al. 1999) or has a focus on direct costs (Meuwissen, Van Asseldonk, and Huirne 2003) with limited attention for price impact and supply chain consequences (Huirne et al. 2002). Mangen, Nielen and Burrell (2002) do study economic consequences from emergency vaccination with the option of selling products from vaccinated animals to the market, but they however study classical swine fever and pigs only. The goal of this article is to address economic consequences of emergency vaccination for foot and mouth disease for all food chains involved. For the

completeness of the analysis we also quantify veterinary costs. In the Netherlands veterinary costs are typically shared between farmers, the European government and the Dutch government (Meuwissen et al. 2006).

Economic consequences from emergency vaccination mainly originate from the perception at the national market that products from vaccinated animals are dangerous for human health. In addition, losses are caused by importing countries not sufficiently trusting that animal products originate from non-vaccinated regions. If vaccinated animals are not destroyed, it roughly takes about eight months before most of the restrictions are lifted. In case of destruction this is six months—about as long as the time period for restrictions if there is no emergency vaccination at all. Also, in the "emergency vaccination but no destruction" strategy, the type of market disruptions is more severe. For instance, all products originating from vaccinated animals must be separately processed and may only be sold within the Netherlands (www.minlnv.nl).

This article presents two different approaches for estimating food supply chain losses resulting from the application of emergency vaccination for controlling FMD-epidemics: (1) a multi-chain and strategy simulation analysis; and (2) a business case on vaccinated pigs. In the first approach we consider all FMD-related food chains, i.e. dairy, beef, pork, sheep and goat meat supply chains, and three control strategies: one without emergency vaccination and two with emergency vaccination (with and without destruction of vaccinated animals after the end of the epidemic). The epidemiological impact of FMD-epidemics and the effect of various control strategies including emergency vaccination are simulated with a spatial, dynamic and stochastic simulation

model. In the second approach we focus on the pork chain and, specifically, on pork from vaccinated pigs that are sold on the market. In the multi-chain analysis, cost parameters are estimated at an aggregated level, i.e. without differentiating between cost factors, chain participants, regions or time frames. In the business case there is a greater level of detail and calculations are specified for multiple scenarios varying on supply volumes of vaccinated pigs and the outlet for products originating from the vaccinated animals, i.e. as fresh pork to retail or as meat products to the meat processing industry. Both approaches have a limited time horizon: in the simulation analysis this is linked to the official guidelines of eight (or, if appropriate, six) months. In the business case the time horizon is limited to the life span of the vaccinated piglets and hogs (about six months).

A multi-chain and strategy simulation analysis

Materials and methods

The epidemiological impact of FMD-epidemics and the effect of various control strategies including emergency vaccination are simulated with a well-documented spatial, dynamic and stochastic simulation model. The model builds on work of, among others, Jalvingh et al. (1999) but with an extension towards emergency vaccination. Results in this article reflect the 95%-percentile of simulation results, i.e. a rather pessimistic scenario of the epidemiological size of an epidemic. Also, we only show the results for an FMD-outbreak in a densely populated livestock area of the Netherlands, i.e. “the middle-east”. This region has on average 1,533 susceptible animals (cattle, pigs, sheep and goats) per km^2. We evaluate the following control strategies:

(1) *stamping-out*, including destruction of infected herds and pre-emptive culling of contact and neighbouring herds;

(2) *combination*, also referring to stamping-out but with limited pre-emptive culling, and with emergency vaccination in a radius of 2 km, followed by the killing of all vaccinated animals after the end of the epidemic; and

(3) *vaccination*, which is the same as "Combination" but without destroying the vaccinated animals after the epidemic has come to an end.

The economic consequences considered relate to (1) veterinary costs of controlling epidemics, such as the value of lost herds and organizational costs; (2) chain losses in affected regions, such as business interruption at farms and losses due to shifting prices for products from vaccinated animals; and (3) chain losses in all other parts of the Netherlands due to market disruptions. Veterinary costs and farm-level business interruption losses build on work of Meuwissen, Van Asseldonk, and Huirne (2003). For the business interruption losses we assume no temporarily leasing of milk quota and no alternative jobs for farmers. These losses range from Euro 0.16 per sheep per day to Euro 6.66 per dairy cow per day. Also veterinary costs are highest for dairy cows: Euro 735 per cow in case of destruction and Euro 8.80 in case of vaccination. Costs of vaccination are lowest for hogs: Euro 1.80 per animal. Chain losses were estimated with sector-wise expert panels, who were brought together early spring 2004. As a point of reference, experts were first presented with chain consequences of the 2001 FMD-epidemic and were then asked to estimate *aggregate* loss percentages for each of the control strategies considered—from which the "Combination" strategy closely matches the 2001-situation.

We did not ask experts to differentiate between cost factors, chain participants, regions or time frames. Aggregate percentages for the "Vaccination" strategy are listed in table 1. Percentages apply for a period of eight months.

TABLE 1

Table 1 shows that for vaccinated animals chain losses are specifically high for pork and white veal, both including an expected price decline of 75%. The high percentage for veal mainly relates to the necessity after vaccination to sell the meat without bones. For the pig sector it is believed that they are faced with severe export difficulties within the European Union. With respect to dairy, table 1 shows that all loss percentages are deemed about equally, i.e. between 9.5% and 10%. The relatively high percentage for "other regions" is caused by the foreseen troubles of exporting dairy products to third countries. Also the other percentages in the last row are negative, implying that experts generally do not believe "other regions" to benefit from epidemics (as was—temporarily—the case during the 1997/98 CSF-epidemic in the Netherlands).

Loss percentages for the other strategies, i.e. "Stamping-out" and "Combination" are equal to those presented in table 1, except that these strategies have a zero-percentage for vaccinated animals, and, also, the length of restrictions is generally shorter.

Results

In the densely populated livestock area considered, i.e. the "middle-east" of the Netherlands, emergency vaccination significantly reduces the epidemiological size of epidemics (see table 2: "Stamping-out" versus "Combination" and "Vaccination"). The duration of the epidemic decreases from 200 to 84 days and the number of infected and

pre-emptively slaughtered herds goes down from over 2,400 to 178. With “Stamping-out” more than 460,000 animals are destroyed, while this is 328,000 and 43,000 for “Combination” and “Vaccination” respectively. The table also shows the amount of milk and meat from vaccinated animals, both in absolute numbers (1,000 kg) and as a percentage of the normal annual production in the Netherlands. Percentages illustrate that for none of the sectors involved, the percentage of produce originating from vaccinated animals is more than 5%.

TABLE 2

In table 3 the epidemiological size of epidemics is converted into economic consequences. Veterinary costs are highest for “Stamping-out” (Euro 421 million) and lowest for “Vaccination” (Euro 94 million). Chain losses at the other hand are highest for “Vaccination” (In total Euro 789 million) and lowest for “Combination” (Euro 588 million). Chain losses related to processing and selling products from vaccinated animals are estimated to be Euro 39 million.

TABLE 3

A business case on vaccinated pigs

Materials and methods

In case of an outbreak of FMD, the application of emergency vaccination without culling the animals afterwards results in the obligation to separate the meat of vaccinated pigs from the meat of non-vaccinated pigs. This results in additional costs for logistics and value loss for the total meat supply chain. Calculations are carried out for ten scenarios, varied on:

a) *supply volumes* of vaccinated pigs: 10, 50, 200, 500 and 1,500 tonnes of slaughter weight per week, based on among others table 2; and
b) the *outlet* for products originating from vaccinated pigs: either as fresh pork to retail (R) or as meat products to meat processing industries (P).

The supply volume of 500 tonnes per week closely matches the situation in table 2, i.e. 16,450 tonnes of pork for a period of eight months.

For each of the scenarios the following cost items are included: inefficiency of slaughter lines, inefficiency of cutting activities, inefficiency of deboning, extra storage costs, extra product items, inefficiency of meat processing, extra order picking costs, extra logistic costs and costs related to value reduction. The latter occurs because of a devaluation of slaughter by-products, a less attractive assortment of meat products at retail level, and the selling to the commonly cheap-buying meat processing industry. Calculations are verified with industry and policy experts.

Results

Results are presented in table 4, both in terms of total costs and per kg of meat products and per kg of slaughter weight. Results show that total costs vary from Euro 0.2 million to over Euro 21 million, depending on volume and market. Expressed per kg of meat product, additional cost vary from Euro 0.60 per kg to Euro 1.69 per kg in the retail alternative, and from Euro 0.82 per kg to Euro 0.96 per kg in the meat processing industry alternative. These loss amounts are mostly lower than the Euro 0.95 per kg from table 1 (i.e. 75% x Euro 1.27/kg). The latter is however an aggregated number covering a longer time horizon.

TABLE 4

From the results from table 4 it can be concluded that the volume of pork from vaccinated pigs should determine the actual marketing strategy. Figure 1 shows a subdivision of costs. Numbers are per kg of meat product. The figure shows that, in all scenarios, value reduction is a major cost factor. These costs cannot easily be reduced. A further important cost factor includes the additional logistic costs, which strongly diminish as volumes increase.

FIGURE 1

Conclusions and discussion

This article studies supply chain losses from applying—the more socially acceptable—strategy of emergency vaccination for controlling livestock epidemics. More specifically we consider the situation in which products from vaccinated animals are actually marketed. Losses occur from the perception at the national market that products from vaccinated animals are dangerous for human health. In addition, losses are caused by importing countries not sufficiently trusting that animal products originate from non-vaccinated regions.

From an epidemiological perspective, emergency vaccination significantly reduces the size of an epidemic, both in terms of the length of an outbreak and in the number of animals killed. However, not destroying the vaccinated animals after the end of the epidemic leads to an additional loss of Euro 200 million for food supply chains involved, from which Euro 39 million directly relates to vaccinated animals. For products from vaccinated animals aggregated chain losses are estimated to be Euro 0.06 per kg of

milk, Euro 0.88 per kg of beef, Euro 0.95 per kg of pork, Euro 1.44 per kg of marbled veal, Euro 4.24 per kg of white-veal and Euro 1.24 per kg of sheep and goat meat.

A business case for chain losses from vaccinated pigs illustrates that losses considerably vary across supply volumes and markets chosen. Smaller volumes, i.e. up to 50,000 kg of slaughter weight per week can better be sold to processing industries, while for larger volumes (200,000 kg of slaughter weight per week and higher) it is less costly to sell the pork as a fresh product to retailers. For pigs, a worst-case scenario of an outbreak of foot and mouth disease in a densely populated livestock area of the Netherlands shows that the amount of slaughter weight per week is about 500,000 kg. Similar calculations for other sectors show that the total amount of products from vaccinated animals for the total period with market restrictions is always less than 5% of the regular production per year for the Netherlands as a whole.

This article fits in the current discussion between governments, industry and consumer organisations about the most *efficient* control strategy on the one hand and *societal and consumer acceptance* of control strategies at the other hand. Although FMD is not infecting human beings, unlike for instance BSE and avian influenza, the impact for food supply chains involved is considered to be rather equal. Calculations in this article are limited to FMD-epidemics in densely populated livestock areas. Also, the business case has a somewhat limited time horizon. Yet, the approaches presented appear very useful in communicating with policy and private market stakeholders, both nationally and internationally, about the supply chain consequences of new responses to

livestock epidemics (in this case: emergency vaccination for FMD). Calculations provide a timely basis for addressing cost sharing issues and loss reducing opportunities.

Acknowledgements

The Dutch Ministry of Agriculture, Nature Management and Food Quality and the Dutch Farmers' Organisation are acknowledged for financing this study. People from industry are thanked for fruitful discussions on this topic. VION is acknowledged for providing data for the business case.

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Table 1. Chain Losses (in Percentage of Default Price) for Vaccination[a]

	Dairy	Beef	Pork	Veal-marbled	Veal-white	Sheep & goat
Default price (Euro/kg)[b]	0.57	2.50	1.27	2.62	5.65	2.25
Chain losses in affected region (%)						
- Vaccinated animals	-10%	-35%	-75%	-55%	-75%	-55%
- Animals under welfare slaughter	n.a.	n.a.	-10%	-10%	-10%	n.a.
- Other animals in affected region	-10%	-5%	-20%	-10%	-65%	-15%
Chain losses in other regions (%)						
- All animals	-9.5%	-5%	-15%	-5%	-25%	-5%

[a]Includes stamping-out of infected herds, limited pre-emptive culling of contact herds, and emergency vaccination of all susceptible herds in a 2-km zone around infected herds. Vaccinated animals are not destroyed after the epidemic has come to an end.

[b]Farm-gate prices. Only for dairy and white veal other prices are used, i.e. factory-gate and slaughterhouse-gate prices respectively.

Table 2. Epidemiological Size of FMD-Epidemics in Densely Populated Livestock Area of The Netherlands for Three Control Strategies[1], and Amount of Dairy and Meat from Vaccinated Animals

	Stamping-out	Combination	Vaccination
Duration of epidemic in days[2]	200	84	84
Infected and pre-emptively slaughtered herds	2,425	178	178
Vaccinated herds	-	1,210	1,210
Herds in welfare slaughter programs	1,389	777	777
Number of herds in affected region	10,484	8,478	8,478
Total number of animals killed	*463,041*	*327,839*	*43,707*
Dairy and meat from *vaccinated* animals over a period of eight months[3]			
- Dairy (1,000 kg)	-	-	66,540 (0.6%)[4]
- Beef (1,000 kg slaughter weight)	-	-	870 (0.4%)[4]
- Veal-marbled (1,000 kg slaughter weight)	-	-	810 (2.2%)[4]
- Veal-white (1,000 kg slaughter weight)	-	-	4,100 (2.8%)[4]
- Sheep & goat (1,000 kg slaughter weight)	-	-	90 (0.4%)[4]
- Pork (1,000 kg slaughter weight)	-	-	16,450 (1.1%)[4]

[a]*Stamping-out*: including destruction of infected herds and pre-emptive culling of contact and neighbouring herds; *Combination*: also referring to stamping-out but with limited pre-emptive culling, and with emergency vaccination in a radius of 2 km, followed by the killing of all vaccinated animals after the end of the epidemic; and *Vaccination*, which is the same as "Combination" but without destroying the vaccinated animals after the epidemic has come to an end.

[b]Number of days from first detection until 30 days after last detection.

[c]The minimum time frame with market restrictions is eight months.

[d]Produce as a percentage of the normal annual production of the Netherlands as a whole.

Table 3. Expected Economic Impact of FMD-Epidemic in Densely Populated Livestock Area of The Netherlands for Three Control Strategies (Million Euro)

	Stamping-out	Combination	Vaccination
Veterinary costs	421	174	94
Chain losses in affected region			
- Business interruption at farm level	65	14	2
- Chain losses from vaccinated animals	-	-	39
- Chain losses from animals under welfare slaughter	2	1	1
- Chain losses from other herds in affected region	132	60	60
Chain losses in other regions	511	512	687
Total losses in the Netherlands	1,132	762	883

Table 4. Additional Chain Costs for Pork from Vaccinated Pigs

	Total costs for whole period[a] (million Euro)	Costs per kg of meat product (Euro/kg)	Costs per kg of slaughter weight (Euro/kg)
Fresh pork to retail			
- 10 (1,000 kg slaughter weight) / week	0.3	1.69	1.13
- 50 (1,000 kg slaughter weight) / week	1.4	1.56	1.05
- 200 (1,000 kg slaughter weight) / week	2.8	0.81	0.54
- 500 (1,000 kg slaughter weight) / week	6.4	0.73	0.49
- 1,500 (1,000 kg slaughter weight) / week	15.6	0.60	0.40
Pork products to processing industry			
- 10 (1,000 kg slaughter weight) / week	0.2	0.96	0.64
- 50 (1,000 kg slaughter weight) / week	0.8	0.92	0.61
- 200 (1,000 kg slaughter weight) / week	2.8	0.82	0.55
- 500 (1,000 kg slaughter weight) / week	7.1	0,82	0.55
- 1,500 (1,000 kg slaughter weight) / week	21.2	0.82	0.55

[a]Defined as life span of piglets and hogs, i.e. about six months.

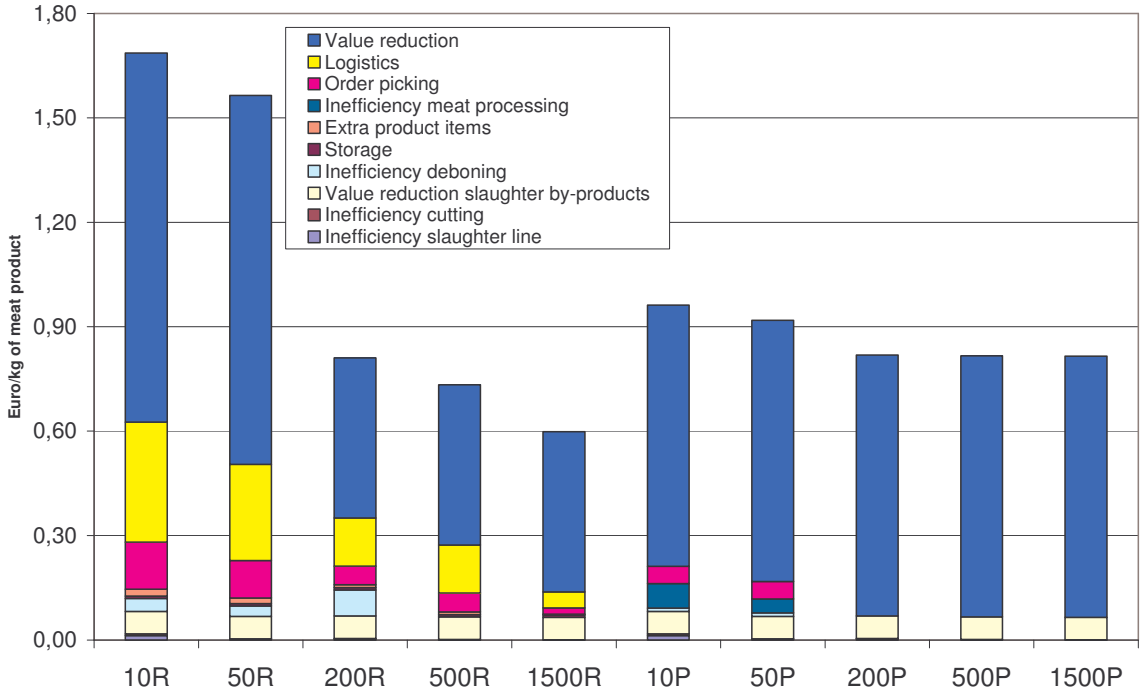

Figure 1. Additional chain costs for pork from vaccinated pigs, marketed to retail (R) and meat processing industries (P). Amounts of pork are in 1,000 kg slaughter weight per week